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Patentanmeldung Nr.	Patent application No.	Demande de brevet n°
	00204046.7	

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Sheet 2 of the certificate
Page 2 de l'attestation

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Application no.:
Demande n°:
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Anmeldetag:
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Applicant(s):
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5621 BA Eindhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Methods, optical recording apparatus using these methods and optical recording medium for use by the methods and the apparatus

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

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Methods, optical recording apparatus using these methods and optical recording medium for use by the methods and the apparatus.

The invention relates to a method for setting an optimum value of a write parameter for use in an optical recording apparatus for writing information on an optical recording medium by a radiation beam, the method comprising a first step of writing a series of test patterns on the recording medium, each pattern with a different value of a write power level (P) of the radiation beam, a second step of reading the patterns to form corresponding read signal portions, and a third step of deriving a value of a read parameter from each read signal portion. The invention also relates to a method for setting an optimum value of write power level of the radiation beam.

The invention further relates to an optical recording apparatus for recording information on an optical recording medium, comprising a radiation source having a controllable value of a write power level for emitting a radiation beam for recording information on the recording medium, a control unit for recording a series of test patterns, each pattern with a different value of the write power level, a read unit for reading the patterns and forming corresponding read signal portions, and first means for deriving a value of a read parameter from each read signal portion.

The invention further relates to an optical recording medium for recording information by irradiating the recording medium by a radiation beam, the recording medium comprising an area containing control information indicative of a recording pocess by which information can be recorded on that recording medium, the control information comprising values of recording parameters for the recording process.

A method and apparatus according to the first paragraph are known from the European patent application no. EP 0 737 962. The apparatus uses a method for setting the optimum write power (P_{opt}) of the radiation beam having the following steps. First the apparatus records a series of test patterns on the recording medium, each pattern with increasing write power (P). Next, it derives the modulation (M) of each pattern from the read signal corresponding to the pattern. It calculates the derivative of the modulation (M) as a

function of the write power (P) and normalizes the derivative by multiplying it by the write power (P) over the modulation (M). The intersection of the normalized derivative (γ) with a preset value (γ_{target}) determines a target write power level (P_{target}). Finally, the target write power (P_{target}) is multiplied by a parameter (ρ) to obtain a write power level (P_{opt}) suitable for recording on the recording medium. The value of the parameter (ρ) is read from the recording medium itself. The test patterns are recorded on the recording medium by applying write power (P) values in a range around a given value (P_{ind}) which is also read from the recording medium itself.

In an optical recording apparatus it is important to record information on optical recording media with the correct power of the laser beam. A media manufacturer can not give this correct power in an absolute way (e.g., pre-recorded on the disc) because of environment and apparatus -to- apparatus deviations for every recording medium and recording apparatus combination. The known method for setting the optimum write power (P_{opt}) takes the different characteristics of the recording media into account by measuring the modulation (M) of the test patterns written on the recording media. Furthermore, this method is independent of the specific recording apparatus. The method is designed for providing a proper setting of the write power for each combination of recording apparatus and recording medium.

However, it is a disadvantage of the known method that it is not always possible to determine an accurate and unambiguous value for the target write power level (P_{target}) and therefore for the optimal value (P_{opt}) of the write power level (P). This is because of the measurement noise introduced during the measurement of the values for the modulation (M) of each pattern. This measurement noise increases with decreasing write power (P) of the test patterns. It appears that even when the measured modulation values are averaged, so as to reduce the measurement noise, sometimes a sort of plateau in the γ-curve occurs preventing the determination of an unambiguous value for the target write power level (P_{target}).

It is an object of the present invention to provide a method according to the opening paragraph which determines an accurate and unambiguous optimum value for a write parameter, from which write parameter an optimal value (P_{opt}) of the write power level (P) may be derived.

This object is achieved when the method of the preamble is characterized in that the method further comprises a fourth step of curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P), and a fifth step of setting an optimum value of the write parameter in dependence on a property of the curve-fitted function.

It is observed that in the known method the noise in the measurement of the read parameter is significantly attenuated by the differentiation step necessary to obtain the normalized derivative (γ). In the method according to the invention this differentiation step is omitted and a function is curve-fitted directly to the values of the read parameter versus the values of the write power level. This curve-fitting may be done by any fitting algorithm such as, for example, the well-known least-squares algorithm. From this curve-fitted function an optimum value of the write parameter is obtained.

In general, any function defining a relation between the read parameter and the write power level (P) having any shape may be used. However, it should be noted that a straight line can very easily and accurately be curve-fitted. Therefore, arranging the values of the read parameter and of the write power level (P) in such a way that a straight line could be curve-fitted is advantageous and should be preferred.

In a version of the method according to the invention the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium. This modulation (M) is computed from the following expression

$$M = ((I_H - I_L) / I_H) \cdot 100,$$

where I_H is the highest level of the amplitude and I_L is the lowest level of the amplitude in the read signal derived from reading information recorded on the information carrier comprising longer marks such as, for example, marks having a length of 14 times the channel bit length when Eight-to-Fourteen Modulation Plus (EFM+) coding is employed.

A version of the method according to the invention is characterized in that the curve-fitted function is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

wherein α and β have values resulting from the curve-fitting, and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

When the values of the modulation (M) times the write power level (P) are plotted versus the write power level (P), a function represented by a substantially straight line can be curve-fitted. Physically this straight line is limited by the lowest write power and the highest write power used when writing the series of test patterns. It is an advantage of this

version of the method according to the invention that a straight line can very easily and accurately be curve-fitted by known fitting algorithms.

The curve-fitted straight line is described by its properties α and β. The optimum value of the write parameter is set to be substantially equal to the value of β, i.e. the value for the power level (P) for which the extrapolated straight line crosses the P-axis. It is a further advantage of this version of the method according to the invention that each straight line has just a single crossing with each of the axes. Therefore, the optimum value of the write parameter can unambiguously be determined because there is only a single crossing of the curve-fitted straight line with the P-axis.

It is also an object of the present invention to provide a method according to the opening paragraph which determines an accurate and unambiguous optimum value (P_{opt}) of the write power level (P) of the radiation beam. The optimum value (P_{opt}) of the write power level (P) is that write power (P) which gives the lowest jitter of the read signal from information recorded on the recording medium.

This object is achieved when the method of the preamble, the radiation beam having a write power level, is characterized in that the curve-fitted function is of the form $P \cdot M = \alpha \cdot (P - \beta)$,

wherein α and β have values resulting from the curve-fitting, the optimum value of the write parameter is set to be substantially equal to the value of β, and the optimal value (P_{opt}) of the write power level (P) of the radiation beam is set to be equal to the optimum value of the write parameter times a multiplication constant (κ).

After the optimum value of the write parameter has been determined, i.e. is set to be substantially equal to the value of β, an optimal value (P_{opt}) of the write power level (P) of the radiation beam is obtained by multiplying the optimum value of the write parameter by a multiplication constant (κ). Thus an optimal value (P_{opt}) of the write power level (P) is found from

$$P_{opt} = \kappa \cdot \beta$$

The value of the multiplication constant (κ) depends on properties of the recording medium on which information is to be recorded. It should be noted that the value for the multiplication constant (κ) can be derived from the values for the parameter (ρ) and for the preset value (γ_{target}) of the known method by the formula

$$\kappa = \rho \cdot (1 + 1/\gamma_{target}).$$

A version of the method according to the invention is characterized in that the multiplication constant (κ) is read from an area on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium.

Because the value of the multiplication constant (κ) depends solely on properties of the recording medium, it can be determined by the manufacturer and pre-recorded on the recording medium during manufacture. Alternatively, the value of the multiplication constant (κ) can be determined by the user and recorded on the recording medium for later use. The method now reads the value of the multiplication constant (κ) from the recording medium when an optimum value (P_{opt}) of the write power level (P) has to be set for recording information on that recording medium.

It is a further object of the present invention to provide a apparatus according to the opening paragraph which determines an accurate and unambiguous optimum value for a write parameter, from which write parameter an optimal value (P_{opt}) of the write power level (P) may be derived.

This object is achieved when the apparatus of the preamble is characterized in that the apparatus further comprises second means for curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P), and third means for setting an optimum value of a write parameter in dependence on a property of the curve-fitted function.

An embodiment of the apparatus according to the invention is characterized in that the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium, in that the curve-fitted function is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

wherein α and β have values resulting from the curve-fitting, and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

An embodiment of the apparatus according to the invention is characterized in that an optimum value (P_{opt}) of the write power level (P) is set in dependence of the optimum value of the write parameter.

An embodiment of the apparatus according to the invention, the read unit operative for reading a value of a multiplication constant (κ) from an area on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium, is characterized in that the optimum

value (P_{opt}) of the write power level (P) is set by multiplying the optimum value of the write parameter by the multiplication constant (κ).

It is a further object of the present invention to provide an optical recording medium for use by the method and the optical recording apparatus of the present invention.

This object is achieved when the optical recording medium of the preamble is characterized in that the control information comprises a value of a multiplication constant (κ).

Because the value of the multiplication constant (κ), used by the method and the apparatus for setting the optimal value (P_{opt}) of the write power level (P), depends solely on properties of the recording medium, it can be determined by the manufacturer and pre-recorded on the recording medium during manufacture.

It should be noted that an optical recording medium is known from the International patent application no. WO 98/25266. However, the control information contained on this known recording medium comprises a preset value (γ_{target}) which, in the known method and apparatus for setting an optimum value for a write parameter, is compared to the values of the normalized derivative (γ) of the modulation (M) versus the write power (P). The optical recording medium according to the present invention comprises a multiplication constant (κ) which is used to obtain an optimum value (P_{opt}) of the write power level (P) by multiplying this multiplication constant (κ) with the optimum value of a write parameter. Furthermore, this optimum value of a write parameter is derived without using a derivative of the modulation (M) versus the write power (P).

The objects, features and advantages of the invention will be apparent from the following more particular descriptions of examples of embodiments of the invention, as illustrated in the accompanying drawings where,

Figure 1 is a diagram of an embodiment of an optical recording apparatus according to the invention,

Figure 2 illustrates two read signal portions from two test patterns,

Figure 3 is a graph showing the measured modulation time the write power as a function of the write power and the curve-fitted function,

Figure 4 is a flow-chart of a version of the method according to the invention, and

Figure 5 shows an embodiment of a recording medium according to the invention.

Figure 1 shows an optical recording apparatus and an optical recording medium 1 according to the invention. Recording medium 1 has a transparent substrate 2 and a recording layer 3 arranged on it. The recording layer 3 comprises a material suitable for recording information by means of a radiation beam 5. The recording material may be of for example the magneto-optical type, the phase-change type, the dye type or any other suitable material. Information may be recorded in the form of optically detectable regions, also called marks, on recording layer 3. The apparatus comprises a radiation source 4, for example a semiconductor laser, for emitting a radiation beam 5. The radiation beam is converged on recording layer 3 via a beam splitter 6, an objective lens 7 and substrate 2. The recording medium may alternatively be air-incident, where the radiation beam is directly incident on recording layer 3 without passing through a substrate. Radiation reflected from medium 1 is converged by objective lens 7 and, after passing through beam splitter 6, falls on a detection system 8, which converts the incident radiation in electric detector signals. The detector signals are input to a circuit 9. This circuit 9 derives several signals from the detector signals, such as a read signal S_R representing the information being read from recording medium 1. Radiation source 4, beam splitter 6, objective lens 7, detection system 8 and circuit 9 form together a read unit 90.

The read signal from circuit 9 is processed in a first processor 10 in order to derive signals representing a read parameter from the read signal. The derived signals are fed in a second processor 101 and subsequently into a third processor 102 which processors process a series of values of the read parameter and based thereon derive a value for a write power control signal necessary for controlling the laser power level.

The write power control signal is connected to a control unit 12. An information signal 13, representing the information to be recorded on the recording medium 1, is also fed into control unit 12. The output of control unit 12 is connected to radiation source 4. A mark on recording layer 3 may be recorded by a single radiation pulse, the power of which is determined by the optimum write power level (P_{opt}) as determined by processor 102. Alternatively, a mark may also be recorded by a series of radiation pulses of equal or different lengths and one or more power levels determined by the write power signal.

A processor is understood to mean any means suitable for performing calculations, e.g. a micro-processor, a digital signal processor, a hard-wired analog circuit or a field programmable circuit. Moreover, first processor 10, second processor 101 and third processor 102 may be separate devices or, alternatively, may be combined into a single device executing all three processes.

Before recording information on medium 1 the apparatus sets its write power (P) to the optimum value (P_{opt}) by performing a method according to the invention. This method is schematically depicted in the flow-chart shown in figure 4.

In a first step 41 the apparatus writes a series of test patterns on medium 1. The test patterns should be selected so as to give a desired read signal. If the read parameter to be derived from the read signal is the modulation (M) of a read signal portion pertaining to a test pattern, the test pattern should comprise marks sufficiently long to achieve a maximum modulation of the read signal portion. When the information is coded according to the so-called Eight-to-Fourteen modulation (EFM), the test patterns preferably comprise the long I11 marks of the modulation scheme. When the information is coded according to the Eight-to-Fourteen Plus modulation (EFM+), the test patterns should comprise the long I14 marks of this modulation scheme. The test patterns are recorded each with a different write power level (P). The range of the powers may be selected on the basis of an indicative power level (P_{ind}) recorded as control information on the recording medium. Subsequent test patterns may be recorded with a step-wise increased write power level (P) under the control of control unit 12. The test patterns may be written anywhere on the recording medium. They may alternatively be written in specially provided test areas on the recording medium.

In a second step 42 the recorded test patterns are read by read unit 90 to form a read signal S_R. Figure 2 shows the read signal portions 18 and 19 obtained from two test patterns written at two different write power levels. The drawn patterns comprise a short mark, a long mark and a short mark, as shown by the signal parts 15, 16 and 17, respectively in both read signal portion 18 and read signal portion 19. An actual pattern may comprise a few hundred marks of different or equal lengths.

In a third step 43 processor 10 derives from the read signal S_R a read parameter for each read signal portion. A possible read parameter is the ratio of the lowest level of the amplitude of a read signal portion, for read signal portion 18 indicated by 'a' in Figure 2, and the maximum level of the amplitude of the same read signal portion, indicated by 'b'. A preferred read parameter is the modulation (M), being the ratio of the maximum

peak-to-peak value of a read signal, indicated by 'c', and the maximum amplitude 'b' of the read signal portion.

In a fourth step 44 processor 101 forms a series of value pairs for the modulation (M) of a pattern times the write power (P) and the write power (P) with which that pattern has been written. The write powers may be taken from the value of the write power control signal during recording the test patterns or, alternatively, from a measurement of the radiation power.

Figure 3 shows schematically the result of the processed read signal obtained from the test patterns; each dot 21 represents a pair of values for the modulation (M) times the write power (P) and the write power (P) of a test pattern. Processor 101 fits a straight line 22 through the measured modulation values (M) times the write power (P), i.e. $M \cdot P$. The fitted straight line is indicated in Figure 3 by a solid line 22. The fitting may be done by the well-known least-squares fitting algorithm. The fitted straight line 22 may be extrapolated. The extrapolated straight line is indicated in Figure 3 by a dashed line 24.

In a fifth step 45 processor 102 determines an analytic expression describing the fitted straight line. This expression is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

where parameters α and β have values resulting from the curve-fitting. The value for the write parameter β determined by the curve fitting is now used by processor 102 to set the optimal value (P_{opt}) for the write power (P). This is done by multiplying this value for the write parameter β with a value of a multiplication constant (κ). So, the optimal value (P_{opt}) for the write power (P) is found from

$$P_{opt} = \kappa \cdot \beta,$$

The multiplication constant (κ) depends on properties of the recording medium 1 and may be pre-recorded in an control area 32 of the recording medium 1. Is so, the multiplication constant (κ) is read from the recording medium 1 by the read unit 90.

It should be mentioned that the value for the write parameter β determined by the curve fitting corresponds to the value of the write power (P) for which the extrapolated straight line 24 crosses the P-axis 26. This value of the write power (P), and therefore of the write parameter β, is indicated by reference number 25 in Figure 3.

Figure 5a shows an embodiment of recording medium 1 provided with a track 30. The track may be circular or spiral and in the form of, for example, an embossed groove or ridge. The area of the recording medium is divided in an information recording area 31 for

recording user information and a control area 32 for storing information relevant for writing, reading and erasing information on the recording medium and in general not intended for recording user information. Control area 32 is marked by a dashed track in figure 5. Information recording area 31 is of a type which is subject to change in an optically detectable property when exposed to radiation above a specific write power level. Information on the recording medium is represented by patterns of marks.

Information is recorded in a track 30 in the information recording area 31 by a recording process in which each mark is formed by one ore more recording pulses of constant or varying write power depending on, for example, the length of the marks to be recorded. The recording parameters for this recording process are stored in the control area 32 in the form of patterns of marks 34 representing the control information indicative of the recording process. Figure 5b shows a strongly enlarged portion 33 of track 30 comprising an example of a pattern of marks 34 in which the control information is encoded.

The value of the multiplication constant κ may be stored as a pattern of marks representing control information in control area 32 of the recording medium 1. When the control area 32 is embossed, the manufacturer of the medium must pre-record the value for κ during manufacture. Alternatively, the user may record the value for κ on the recording medium during, for example, initialization of the recording medium.

Alternatively, a recording medium provided with control information in a different manner may be used. Such an alternative recording medium is, for example, encoded in a periodic modulation of an embossed groove (known as a wobble). Now the value for the multiplication constant κ is coded in an auxiliary signal which auxiliary signal is used to, for example, frequency-modulate the wobble. A description of such a recording medium may be found in EP 0 397 238.

Although the invention has been explained by an embodiment using the read signal modulation (M) as read parameter and a disc shaped recording medium, it will be clear to a skilled man that other read parameters and other shapes of the recording medium can be employed in the invention. For example, the jitter of the read signal can be used as the read parameter.

CLAIMS:

1. A method for setting an optimum value of a write parameter for use in an optical recording apparatus for writing information on an optical recording medium (1) by a radiation beam (5),

the method comprising a first step (41) of writing a series of test patterns on the recording medium, each pattern with a different value of a write power level (P) of the radiation beam,

a second step (42) of reading the patterns to form corresponding read signal portions (18, 19), and

a third step (43) of deriving a value of a read parameter from each read signal portion,

characterized in that the method further comprises a fourth step (44) of curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P),

and a fifth step (45) of setting an optimum value of the write parameter in dependence on a property of the curve-fitted function.

2. A method according to claim 1, wherein the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium.

3. A method according to claim 2, characterized in that the curve-fitted function (22) is of the form $P \cdot M = \alpha \cdot (P - \beta)$,

wherein α and β have values resulting from the curve-fitting,

and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

4. For use in an optical recording apparatus for writing information on an optical recording medium (1) by a radiation beam (5) having a write power level, a method for setting an optimum value (P_{opt}) of the write power level (P) of the radiation beam using the

method of claim 3 for setting an optimum value of a write parameter, characterized in that optimal value (P_{opt}) of the write power level (P) is set to be equal to the optimum value of the write parameter times a multiplication constant (κ).

5. A method according to claim 4, characterized in that the multiplication constant (κ) is read from an area (32) on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium.

6. An optical recording apparatus for recording information on an optical recording medium (1), comprising a radiation source (4) having a controllable value of a write power level for emitting a radiation beam (5) for recording information on the recording medium,

a control unit (12) for recording a series of test patterns, each pattern with a different value of the write power level,

a read unit (90) for reading the patterns and forming corresponding read signal portions (18, 19), and

first means (10) for deriving a value of a read parameter from each read signal portion,

characterized in that the apparatus further comprises second means (101) for curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P), and

third means (102) for setting an optimum value of a write parameter in dependence on a property of the curve-fitted function.

7. An apparatus according to claim 6, characterized in that the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium, and in that

the curve-fitted function (22) is of the form $P \cdot M = \alpha \cdot (P - \beta)$,

wherein α and β have values resulting from the curve-fitting,

and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

8. An apparatus according to claim 6 or 7, characterized in that an optimum value (P_{opt}) of the write power level (P) is set in dependence of the optimum value of the write parameter.

9. An apparatus according to claim 8, the read unit (90) operative for reading a value of a multiplication constant (κ) from an area (32) on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium, characterized in that the optimum value (P_{opt}) of the write power level (P) is set by multiplying the optimum value of a write parameter by the multiplication constant (κ).

10. An optical recording medium (1) for recording information by irradiating the recording medium by a radiation beam (5), the recording medium comprising an area (32) containing control information indicative of a recording process by which information can be recorded on that recording medium, the control information comprising values of recording parameters for the recording process,

characterized in that the control information comprises a value of a multiplication constant (κ) for use in the method according to claim 5 or the apparatus according to claim 9.

ABSTRACT:

Methods and an optical recording apparatus using these methods are described in which an optimum write power of a radiation beam in the apparatus is set by writing a series of test patterns on the optical recording medium, forming a read signal from the patterns and processing the read signal. This processing involves fitting a function, preferably a straight line, to parameters obtained from the read signal without having to perform a differentiation step. Also an optical recording medium for use by the methods and the apparatus is described.

Fig. 1

1/3

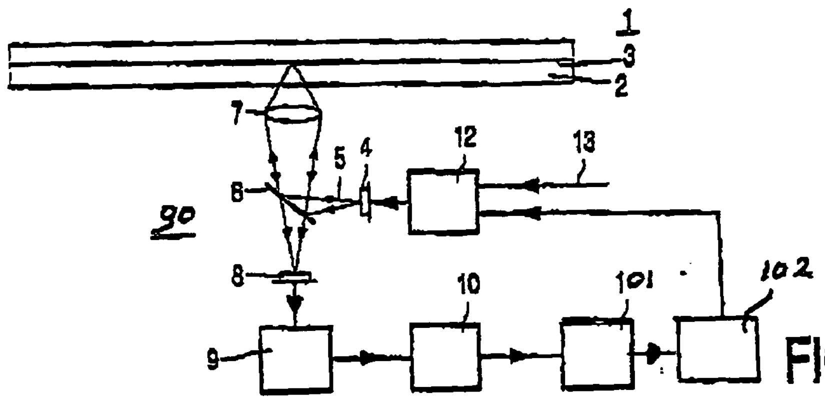


FIG. 1

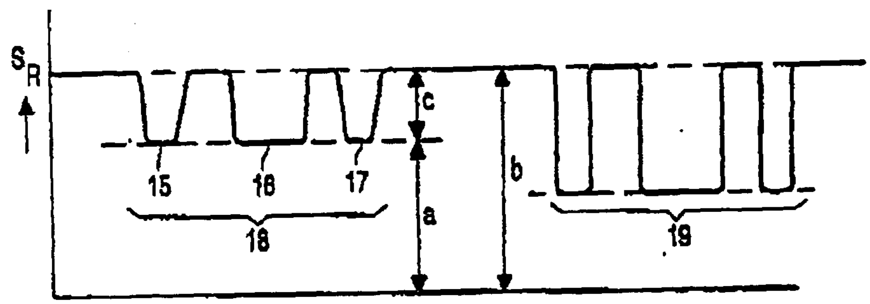


FIG. 2

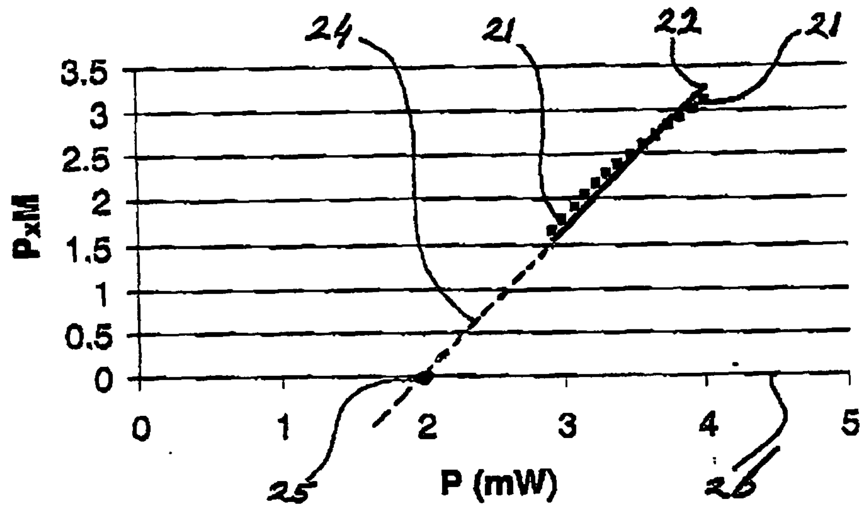
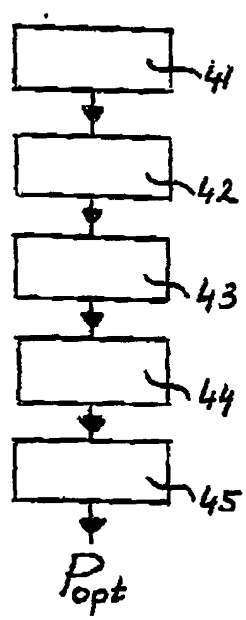

24
21
22
21
3.5
3
2.5
2
1.5
1
0.5
0
PxM
0
1
2
3
4
5
P (mW)
25
23

FIG. 3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42
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Popt

FIG. 4

3/3

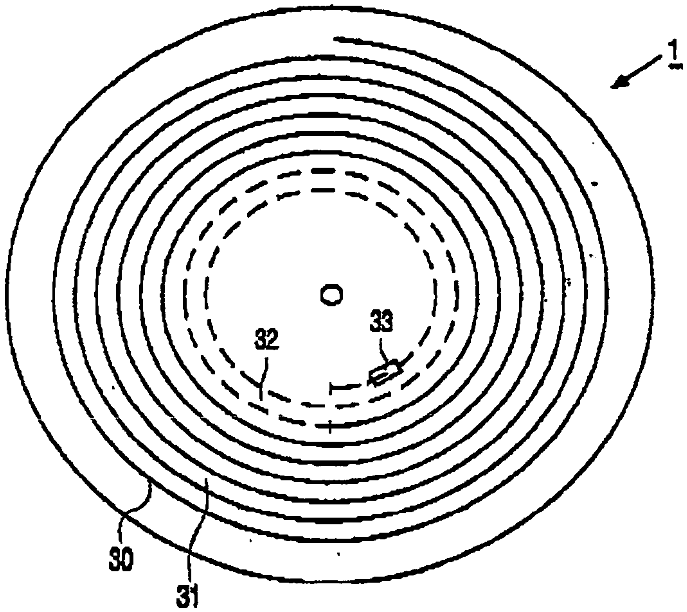

FIG. 5A

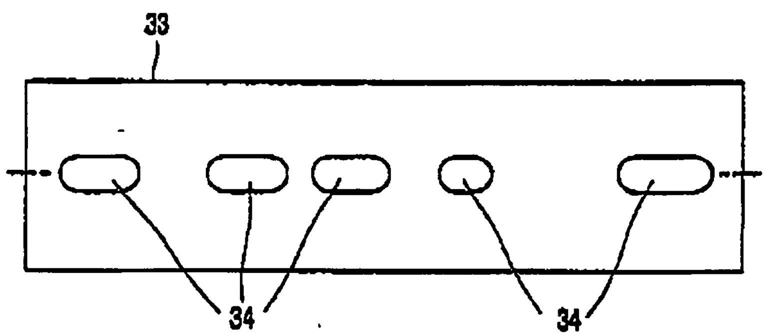

FIG. 5B

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